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Co-operative learning processes of students: A longitudinal multilevel perspective

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Background. This article describes the outcomes of a longitudinal, multilevel observational study in which the relationship between the processes of co-operation and giving explanations was compared between classes trained in communication skills and classes that were untrained.

Aims. This study examined the effects of training in basic communication skills on the processes of co-operation and giving explanation in co-operative groups. In particular, the study investigated: (a) How the processes of co-operation and giving explanations develop over time; (b) How the underlying processes of co-operation and giving explanations are related; (c) Which factors at the student and class level facilitate or hinder these processes.

Sample. The study involved 192, Year 6 primary school children (mean age = 134.3 months) who worked in four-person, mixed ability, gender-balanced groups on a social studies unit of work for 12 weeks.

Results. The students in the trained classes were more co-operative and gave more explanations to each other than their peers in the untrained classes. Giving solicited explanations could be traced back to co-operation and this process was enhanced by ability. In other words, the higher the individual ability levels of the students, the more co-operation was transformed into giving solicited explanations. Furthermore, over and above the effects of student ability, the higher the class' ability level, the more explanations the students gave.

Conclusion. The results of this study are useful in explaining why high-ability students benefit more from co-operative learning than low-ability students and why solicited explanations are more effective than unsolicited explanations. By

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opening the black box of co-operative learning, our analysis enables us to attribute the effects of co-operative learning to peer interactions with more able peers and this is promoted by class ability level. These factors have been mentioned in the literature as a possible explanation of 'contextual effects' but not investigated empirically.

Research has shown that co-operative learning has been used successfully to promote learning achievements across a range of curriculum areas from narrative writing in small groups (Zammuner, 1995), problem-solving in mathematical tasks (Hoek, Terwel, & van den Eeden, 1997), to conceptual understanding in science (Lonning, 1993). In the social area, it influences the development of positive student attitudes and behaviours (Bennett, 1991; Shachar & Sharan, 1994) and motivation to learn (Sharan & Shaulov, 1990). In fact, Cohen (1994) argues that it is no longer necessary to defend co-operative learning as an instructional strategy that promotes achievement. However, while support for co-operative learning is unequivocal, few studies have attempted to identify the variables that mediate the relationship between group experiences and learning outcomes (Gillies & Ashman, 1998). Identifying these variables is crucial to understanding not only which ones mediate the teaching-learning process but also how they influence this process. In essence, what is it that happens in groups that affects group behaviours, interactions and learning?

The aim of this article is to examine the relationship between *co-operation* and *giving explanations*. In effect, the present article aims to describe some unknown mechanism by which the process of co-operation among students in groups is transformed into giving explanations. Co-operative behaviour is conceived as socially-orientated behaviour, trying to understand the perspective of others, being empathic and responsive, actively listening to others, and working together on group activities. Giving explanations refers to more specific verbal interactions and is broken into two categories: (a) unsolicited explanations (i.e., giving detailed or elaborated help when it was not requested) and (b) solicited explanations (i.e., giving detailed or elaborated help in response to a request) (Gillies & Ashman, 1996; Webb, 1982, 1985, 1992). The following factors that facilitate or hinder the transformation of co-operation into giving explanations will be included in the analysis: (i) gender and ability at the student level and (ii) class ability and training in communication skills at the class level.

The data for this article originated from a study by Gillies and Ashman (1996). Those data uniquely allow us to seek answers to questions on the transformation process between co-operation and giving explanations since the data base contains observations on those variables at four points in time. The group activities were developed in the context of a social studies curriculum in which students were challenged to solve problems in different ways and from different perspectives.

In the rest of this article, the theory and hypothesis, the methods and design of the study, the model of analysis, the data, and the outcomes will be successively described. Finally, we formulate the conclusion and discuss the findings in which the black box of co-operative learning is opened to a certain extent.

Theoretical background: Processes in co-operative groups

Numerous studies have suggested potential mediating variables in explaining the effects of co-operative learning, for example, the quality of peer interaction (i.e., helping behaviours) (Cohen, 1994; Johnson & Johnson, 1989, 1990). Although there is ample evidence that certain co-operative learning methods that have no overt social skills training make a substantial contribution to achievement (Slavin, 1995), presumably through enhanced peer interaction, it is also clear that co-operation can be facilitated by establishing two conditions. First, groups need to be structured so that students are dependent on each other (Johnson, Johnson, & Holubec, 1990). Second, students need to be taught the interpersonal and small-group skills that are necessary for successful co-operation (Johnson & Johnson, 1990). When these conditions are met, students are more likely to work together to attain mutual goals (Hertz-Lazarowitz, 1989; Sharan & Shaulov, 1990). Furthermore, they develop an implicit understanding of the unanimity of purpose of the group and the need to help and support each other's learning (Sharan & Shaulov, 1990).

However, while helping behaviours are particularly important for facilitating group involvement and members' understanding of the task, not all helping behaviours are helpful to the recipient. In a series of studies that examined students' verbal interactions as they worked together in groups, Webb (1982, 1985, 1989, 1992) found that explanations received in response to requests for help were positively related to achievement whereas non-explanatory statements were not. When students give explanations to each other in response to requests for help, they are often challenged to reorganise and clarify their own knowledge and understandings in order to be able to provide help that can be useful to the recipient (Wittrock, 1990). In contrast, giving non-elaborated help does not involve as much cognitive restructuring and is not strongly related to achievement for either the explainer or the recipient (Webb, 1989). Furthermore, Webb found that receiving explanations that were not specifically requested were not related to achievement.

While co-operative learning has a positive effect on students' helping interactions and learning (Gillies & Ashman, 1996), research also shows that students of different ability levels differentially benefit from learning in co-operative groups (Leechor, 1988; Webb, 1982, 1989, 1991; Webb & Farivar, 1994). For example, Gillies and Ashman (1997) found that while benefits accrued to students in all ability levels as a result of the co-operative group experience, high-ability students were more active in co-operative groups and provided more explanations than their low-ability peers. Hoek *et al.* (1997), reported similar results. They attributed the gains made by the low-ability students to the specific support the students received from other group members. Even though there is evidence that low achieving students benefit from co-operative learning, low ability students' passivity impedes learning in group contexts (Dale, 1993; King, 1993; Mulryan, 1992, 1995; Ross & Cousins, 1995).

Today more is known about co-operative learning than two decades ago; however there are still many unanswered questions regarding the processes involved in how students co-operate and help each other. While in general, strategy training contributes to learning in co-operative groups (Hoeks *et al.*, 1997; Hoek, Van den Eeden, & Terwel, 1999; Webb & Farivar, 1994), questions still remain about how specific processes like 'giving explanations' may be fostered by instruction and training and how these

processes are related to learning outcomes. Although the review by Webb (1989) gives some indications from correlational studies, she also expresses cautions about the causal direction of the findings from these studies. Important questions still remain. For example, how does co-operation and giving explanations develop over time? What student factors, both at the individual and class level, affect co-operation and giving explanations?

Two basic processes in co-operative learning are the focus of this study. The first is the *social process of co-operation*. This includes such behaviours as listening to others, trying to understand the perspective of others, and being empathic and responsive to each other's needs (Ivey, 1994). The second refers to the more *specific verbal interactions* that are related to learning such as giving explanations or providing elaborated help such as step-by-step descriptions of how to solve a problem or part of a problem (Webb, 1992). In giving specific help to each other, Webb (1982, 1985, 1992) has identified two types of explanations which students provide:

- (a) Unsolicited explanations includes giving detailed descriptions of a solution to a problem or elaborated help when it was not requested.
- (b) Solicited explanations includes giving detailed descriptions of a solution to a problem or elaborated help in response to a request for help.

While there is some evidence that suggests that solicited explanations are more beneficial for both the explainer and the receiver than unsolicited explanations (Webb, 1991, 1992; Webb & Farivar, 1994; Webb, Troper, & Fall, 1995), there is little information available on how these two types of explanations differentially effect learning outcomes. Why is giving and receiving solicited explanations more effective? And how can giving solicited explanations be promoted?

From a cognitive perspective it can be argued that, in general, giving solicited explanations rather than unsolicited explanations is more beneficial. In giving solicited explanations, students are more likely to be aware of what others do not understand and give explanations that can be easily understood. In so doing, they are required to reorganise and clarify the material in new ways which often helps them to understand the material better (Webb & Farivar, 1994; Wittrock, 1990). In contrast, providing unsolicited explanations may not require as much cognitive reorganisation because the giver has not been forced to consider the other's perspective (i.e., they have not been specifically asked for an explanation) on a problem and merely provides explanations which s/he believes will be helpful. From the receiver's perspective, a solicited explanation is likely to be more beneficial than an unsolicited explanation because it has been specifically requested and is likely to be given at a time when the receiver is more receptive to using the help. The act of articulating a request for help requires that the help seeker rehearse his/her knowledge to identify a specific need, make that understanding accessible to conscious scrutiny when verbalising the need, and reorganise his/her thinking to express the need to an audience (Ross & Cousins, 1995). Thus, solicited explanations seem to be preferable for both the giver and the receiver.

Furthermore, there is little information on how giving solicited explanations can be promoted by training in communication skills and how giving solicited explanations is

influenced by factors such as gender, student- and class-ability levels. This lack of information into the underlying processes and the factors involved has meant that researchers have only been able to surmise the effects of each on learning.

Research questions and hypotheses

Students who give more explanations benefit more from learning in co-operative groups in social studies and mathematics than students who give fewer explanations (Gillies & Ashman, 1996; Webb, 1989, 1992). Thus, there is substantial evidence concerning the relationship between giving explanations and learning gains. However, less is known about how giving explanations may be promoted by training students in basic communication skills. Therefore, the general question this observational study seeks to answer is: What are the effects of training in basic communication skills on the processes of co-operation and giving explanations in co-operative groups? In particular:

1. How do the processes of co-operation and giving explanations develop over time?
2. How are the underlying processes of co-operation and giving explanations related?
3. Which factors at the student and the class level facilitate or hinder these processes?

The general hypothesis of this article is that training in basic communication skills promotes *co-operation*. However, while co-operation by itself does not automatically lead to students *giving solicited explanations*, it does create a working milieu that helps to make students more aware of the needs of others in their group, including the readiness to provide help and assistance. Being aware of the needs of others and responsive to others' specific requests is a basis for providing more specific help such as giving explanations, especially solicited explanations. Giving solicited explanations is more beneficial than giving unsolicited explanations. Giving solicited explanations is, in turn, seen to be a key variable in the transformation process from co-operation to the learning gains obtained by individual students. The chain of relationships can be conceived as follows: (1) training in communication skills, (2) co-operation, (3) giving (solicited) explanations and (4) learning outcomes.

Based upon the general hypothesis and the theoretical relationships between the processes that operate in co-operative groups and their facilitating factors, the following research hypotheses are proposed:

I. The time hypothesis

This hypothesis proposes that co-operative learning develops over time and there will be an increase in co-operation and in giving explanations from the first to the fourth observation for students working in co-operative groups. This increase is expected because of a self-enforcing process in which students experience the benefits of co-operation and giving explanations.

II. The relationship between co-operation and explanations hypothesis

This hypothesis concerns the relationship between co-operation and giving explana-

tions. These two processes are thought to be related although co-operation by itself does not automatically lead to students giving explanations. Co-operation, however, does create a working environment that helps to make the students more aware of the needs of others in the group, including the need to provide help and assistance. Explanations which are offered in this context are more likely to be given in response to students' needs than explanations provided in contexts not related to co-operation. Furthermore, if explanations are given as a consequence of a more general pro-social, co-operative attitude, then it is more likely that the help provided will be at a level that is 'tuned-in' to the needs of the receiver. In particular, this hypothesis concerns the different origins of solicited and unsolicited explanations. It is expected that co-operation is the basis from which solicited explanations emerge because of helpers' responsiveness to the needs and perspectives of other students. Thus, co-operation is a determinant of solicited explanations which is assumed to be a facilitating factor in 'fine tuning' the help provided, while unsolicited explanations originate from other sources and do not necessarily lead to an adequate response.

III. The differential effect hypotheses

A. The student ability hypothesis

High- and low-ability students will participate differently in co-operative groups. As a consequence of their superior 'resources', high-ability students have more opportunities to co-operate and to give explanations than their low-ability peers. More specifically, high-ability students are more successful in transforming co-operation into giving explanations as compared to their low-ability peers.

B. The gender hypothesis

In various process studies it has been shown that male and female students participate differentially in classes and small groups. Because of status differences, male students will have more influence in the groups and, by implication, obtain higher scores on co-operation and giving explanations than female students (Canada & Pringle, 1995; Perrenet & Terwel, 1997; Webb, 1982).

IV. The class level hypotheses

A. The mean class-ability level hypothesis

Interaction processes in small groups are different from class to class, and depend on class composition characteristics such as the mean ability-level of the class (Van den Eeden & Terwel, 1994; Willms, 1985, 1986). It is hypothesised that individual students are more often engaged in co-operation and in giving explanations in classes with a higher mean class-ability level because they are in a richer learning environment (Dar & Resh, 1994).

B. The training in basic communication skills hypothesis

This hypothesis is based on the expectation that co-operation can be learned by training classes in basic communication skills such as listening to others, trying to understand the perspective of others, giving positive feedback and being empathic and responsive to each other's needs. Students in classes who are trained in strategies for working together in co-operative groups will outperform their untrained counterparts in co-operation and in giving explanations. This hypothesis is based on studies into the effects

of strategy training on student learning (Gillies & Ashman 1996, 1997; Hoek *et al.*, 1997, 1999; Webb & Farivar, 1994).

These hypotheses will not be tested separately but in one complex theoretical model for multilevel analysis which takes simultaneously into account the mutual relationship between the variables and in which the relationship between co-operation and giving explanations is the centre of the model. Special attention will be given to the differences in the genesis of solicited and unsolicited explanations as the dependent variables in the model. The effect of giving explanations on the transformation process from pre-test to post-test (i.e., learning gains) is not included in this analysis. Firstly, it is omitted to avoid unnecessary complexity of the model and the analysis, and secondly, because this effect can be assumed on the basis of research evidence from others (Gillies & Ashman, 1996, 1997; Webb, 1992). For reasons of conceptual completeness pre-test and post-test are depicted in the model (see Figure 1).

Figure 1. Model for the multilevel analysis

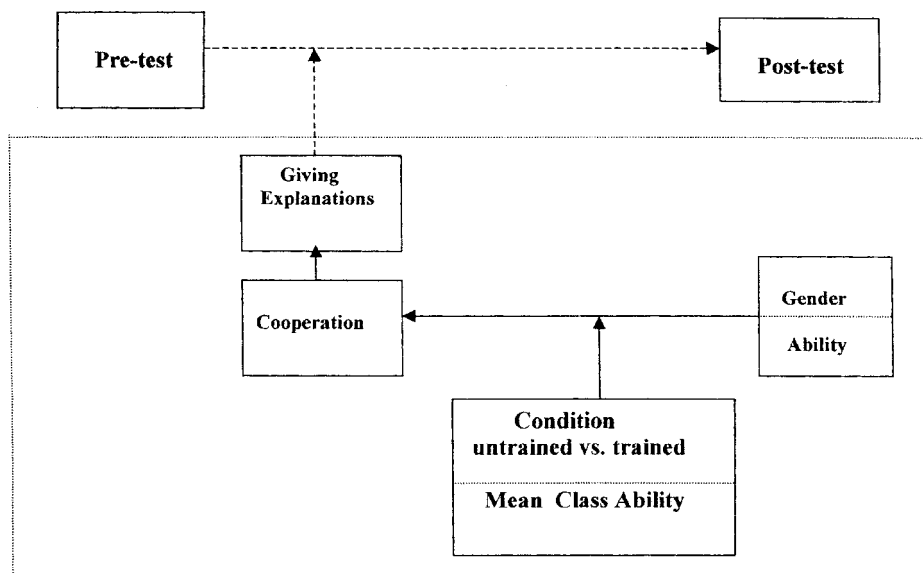


Figure 1 need some clarification, which will be enlarged later on in the description and interpretation of Figures 3 and 4 in the results section. An arrow from box to box refers to the effect of an independent variable on the dependent variable. An arrow from a box to another arrow represents an interaction effect. As a result of the analysis, a coefficient will be given for each significant effect. Later on an example with coefficients will be given at Figures 3 and 4.

Method

In this study an experimental group design is used in which co-operative and verbal interaction processes were observed in the trained and untrained groups at four time points (Weeks 3, 6, 9, 12) during the intervention. The sample involved 192 students in eight classes across eight schools in Brisbane, Australia. The students were identified as having high- (32 males, 16 females), medium- (47 males, 57 females) or low-ability (17 males and 23 females) based on their performances on a test of general ability (General Ability Test F; de Lemos, 1982). A stratified random assignment procedure was applied by the researchers so that each gender-balanced group consisted of one high-, two medium-, and one low-ability student.

Ten teachers from eight classes participated in the study and all agreed to establish teams of four student groups in their classrooms and to teach a Social Studies unit, entitled 'World Exploration' (Queensland Department of Education, 1987). After training (outlined below), the students worked in their groups for one hour, three times a week, for 12 weeks.

The groups assigned to the experimental (trained) condition participated in two one-hour training sessions which were conducted by their teachers over two consecutive days. Students in the control condition were engaged in other activities (e.g., the school library, under guidance of another teacher). Each session was designed to teach the procedures that students would follow during group activities. In the first session they were given information about the social studies unit, the types of activities involved, and the resources available. They were told that they would be responsible for breaking the task into smaller components (each with a subgoal), and accepting responsibility for completing one of those smaller tasks that would contribute to the achievement of the group goal, such as keeping a written record of the outcomes of the learning activities. The second session focused on practising interpersonal skills (e.g., active listening to a speaker, providing constructive criticism of ideas; and accepting responsibility for one's behaviour) and collaborative skills (e.g., sharing tasks fairly, taking turns, resolving problems strategic and democratic; taking the other person's perspective; clarifying differences in opinion). The students were told to use these skills to help them develop their own set of group rules for working together. The control students in the untrained condition were only introduced to the unit and told to work together to attain the group goal.

Group activities

The group activities were developed around the social studies unit and designed to challenge the students to think of different ways of solving problems.

- (a) A first activity concerns recall and comprehension. For example, a problem-solving activity at the recall and comprehension levels (Bloom, 1976) required the students to list the types of foods taken on the voyages by explorers in the 1600s and to consider how it was cooked and stored.
- (b) A second activity required the students to think of the many ways of preserving food on a long sea voyage and document the procedures. This activity reflected Bloom's third level, application.

- (c) In a third type of activity students were asked to compare and contrast different situations or events. For example, the students were asked to compare the sailing ships of old with their modern counterparts and note their similarities and differences.
- (d) A fourth activity required the students to imagine they were an early explorer who was going to search for the great inland sea in Australia and consider the planning they would need to do for their trip. These latter activities required the students to analyse and synthesise information and reflected a higher level of understanding than those mentioned previously.
- (e) Finally, activities that required the students to evaluate and justify their answers were considered the most complex because they required the students to simultaneously consider and evaluate different situations, perspectives, or arguments (Bloom, 1976). An activity at this level required the students to document the provisions they would need for a long sea voyage and be prepared to justify their selections.

Prior to the commencement of the group activities, the teachers introduced the students to an introductory, two-week section from the social studies unit on World Exploration. This section was taught by each class teacher and was designed to familiarise the students with the different types of problem-solving activities they would work on in their groups.

Procedure

Before the investigation began, discussions were held with the classroom teachers on the importance of the random assignment of students to groups as determined by the researchers, the procedure for establishing the Trained and Untrained groups, and the planned small group activities for the social studies unit.

As none of the teachers had used co-operative learning procedures in the classroom on a regular basis, they all received instruction in the small group, interpersonal skills and processes to enable them to teach these skills to students in the Trained groups.

The teachers began each group session by following the procedures outlined by Webb *et al.* (1995) for introducing the activity, demonstrating procedures for working on it, and providing follow-up practice. The teachers were asked to encourage the students to work together in their groups and only to provide assistance on the academic aspects of the work unit and only after the students had first sought help from other group members.

The students in both the trained and untrained conditions worked in their groups for one hour per day, three times per week. All students were videotaped prior to the study and familiarised with the audio-visual equipment. Previous researchers have indicated that reactivity to videotaping is short-lived (Christensen & Hazzard, 1983) and this was also found in the present study.

Each group was taped for 13 minutes and 20 seconds (representing the 40, five-second intervals of observational time for each child in the four-person group) and no group was taped twice in the same day. The study continued for 12 weeks with the groups from both conditions being videotaped on four occasions.

*Conditions**Trained condition*

The teachers who participated in the study agreed to introduce small-group activities in their classrooms as part of their social studies programme and to provide the opportunities for the students to work in these small groups for three, one-hour sessions per week for the duration of the study. The students assigned to the trained condition participated in two training sessions in basic communication skills designed to teach small-group procedures and the interpersonal behaviours believed to promote group co-operation (Egan, 1997; Horton & Brown, 1990; Ivey, 1994; Johnson & Johnson, 1990). Each training session lasted one hour and was conducted by the classroom teachers over two consecutive days (see also the Method section for a description of the treatment).

Untrained condition

Groups assigned to the untrained condition were introduced by their teachers to the social studies activities and the resources available over two consecutive days. These students did not participate in the interpersonal and small-group training sessions given to the students in the trained condition; they were only told to co-operate and were given the same time as the students in the trained condition to discuss how they were going to work together in groups.

Variables: Student ability

Student ability was measured by the ACER General Ability Test F (GAT Test F). This is a group-administered test developed for the Australian Council for Educational Research (ACER) as a screening device of general reasoning ability for students between ages 10 and 15 years (de Lemos, 1982). It comprises 76 items covering four main categories:

- (a) verbal comprehension (e.g., synonyms or definitions, opposites, sentence completion, and scrambled sentences),
- (b) verbal reasoning (verbal analogy, verbal classification, word or letter matrices problems, and problems involving inference or logical selection),
- (c) quantitative reasoning (e.g., number series and arithmetic reasoning items), and
- (d) figural reasoning (e.g., figure analogies, series completion, and pattern matrices).

Two measures of reliability were obtained for the GAT Test F. Reliability coefficients for alternative forms ranged from .87 to .91. The measures of internal consistency provided reliability coefficients ranging from .93 to .95. In addition, a correlation of .90 has been found between the GAT Test F and the Otis-Lennon School Ability Test (Otis & Lennon, 1993).

The students were required to answer as many questions as they could in the 30 minutes allotted to complete the test. Raw scores were obtained by counting the number of correct answers and the outcomes were converted into stanine scores.

Variables: Student behaviours and verbal interactions

A two-part observation schedule was used to compile information on student

behaviours and verbal interactions. The first part of this schedule was adapted from a coding system developed by Sharan and Shachar (1988). The focus in this study is on co-operative behaviour (i.e., socially-orientated behaviour, active listening, working together on group activities). Momentary time sampling was used to code co-operative behaviour at 5-second intervals for group members.

The second part of the observation schedule was adapted from a coding system developed by Webb (1985). The focus in the present study is on two interaction variables: (a) unsolicited explanations (i.e., giving detailed or elaborated help when it was not requested) and (b) solicited explanations (i.e., giving detailed or elaborated help in response to a request). The frequencies of these interactions were tallied across a continuous interval.

Two observers who were blind to the experimental condition coded a common 20% of videotape (five hours). Inter-observer reliability ranged from 93% to 95% across the behaviour states and 91% to 95% across the verbal interactions.

The multilevel model

Since the study is directed on processes over time of various students, and students belong to different classes, the multilevel longitudinal model of analysis is used. In order to investigate differential effects (e.g., the student ability hypothesis) ability was used as a continuous variable because this is more accurate and informative than dichotomising the student group into high- and low-ability students. The time-ordered measurement moments, students and classes constitute the distinctive levels (Bryk & Raudenbush, 1992; Goldstein, 1995; Hoeksma & Koomen, 1993; Kreft & De Leeuw, 1998; Longford, 1995; Rashbash & Woodhouse, 1995; Snijders 1996; Yang & Goldstein, 1996). The following level structure was used:

Level I: Occasion level with variable:

- (i) Time

Level II: Student level with variables:

- (i) Gender
- (ii) Student Ability
- (iii) Co-operation

Level III: Class level with variables:

- (i) Mean Class Ability
- (ii) Condition (Trained/Untrained)

See Appendix 1 for the descriptions and equations of the multilevel model.

Results

Results of the analysis

This article is restricted to the necessary descriptives before presenting the outcomes of the ML-analysis. An elaborated conventional analysis on the same database can be found in the article of Gillies and Ashman (1997). First, the descriptives and correlations of the variables included are given.

The time-dependent variables are depicted in the upper part of Table 1a. The

Table 1a. Descriptives of the variables in the model

Time-dependent variables	time = 1	time = 2	time = 3	time = 4 (min-max)	
<i>Unsolicited explanations</i>					
Mean	4.30	4.84	4.73	4.47	(0–9)
Standard deviation	2.98	2.94	3.06	2.73	
<i>Solicited explanations</i>					
Mean	2.62	2.68	2.64	2.77	(0–9)
Standard deviation	2.31	2.38	2.54	2.34	
<i>Co-operation</i>					
Mean	27.92	27.87	27.46	27.43	(5–52)
Standard deviation	5.17	5.45	4.85	4.86	
—					
<i>Time-independent variables</i>					
—					
	Mean	Standard deviation	(min–max)		
<i>Student level</i>					
Gender	.50				
Ability	4.13	1.80	(0–9)		
<i>Class level</i>					
Condition	.50				
Mean ability	4.13	.26			

Table 1b. Correlations between process variables by groups

	coop	unsol	sol	coop	unsol	sol
<i>Total sample</i>						
Coop						
Unsol. explanations	.303					
Sol. explanations	.498	.451				
Gender	(male)			(female)		
Coop						
Unsol. explanations	.323			.290		
Sol. explanations	.512	.465		.490	.430	
Condition	(exp.)			(control)		
Coop						
Unsol. explanations	.124			.009	.089	
Student ability	(low)			(high)		
Coop						
Unsol. explanations	.319			.236		
Sol. explanations	.481	.488		.510	.402	

descriptives (means and standard deviations) show that there are minor fluctuations in (solicited and unsolicited) explanations and co-operation over time. The lower part of Table 1a contains the descriptives of the time-independent variables at student and class level which are determined at the beginning of the experiment. Table 1b gives the correlations between the process variables by groups. These correlations give a first

impression of the relations between the process variables which will be investigated more thoroughly in the context of our theoretical model.

Before presenting the outcomes of the multilevel analyses something has to be said about the meaning of the intercepts and the coefficients in Tables 2–4. We take Table 3 as an example. The intercept (-11.53) is an identical standard value for each student. The coefficients in the fixed part can be viewed as the conventional unstandardised regression coefficients. For example, in Table 3, the coefficient 2.99 means that a change of one unit on the 'student-ability' scale will result in a change of 2.99 units, on the 'unsolicited explanations' scale. The descriptives from Table 1 (means) can be used to estimate the relative magnitude of the effects for an average student by multiplying the coefficient by the corresponding mean for 'student ability'. In estimating the effects for non-average cases, values between the min and max values from Table 1 can be used.

Let us also give an example of a class level variable from Table 3 by referring to the coefficient $-.55$. The higher a class' mean ability, the less a student's ability will result in giving unsolicited explanations within that class (coefficient $-.55$), i.e., an increase of one unit-point in 'mean class ability' will result in a decrease of .55 point on the scale of unsolicited explanations, and vice versa. This is an interaction effect which can be interpreted as a slowing-down effect of the class (mean class ability) on the process of transition of student ability into the giving of Unsolicited explanations (see also Figure 3 for a graphical representation).

The coefficients in the random part of Table 3 refer to the variances of disturbance terms that are left after introduction of the time, student- and class variables in the analysis. To put it differently, the random part concerns the residual (unexplained) variance after introducing all variables in the analysis. The variance left at student level is also called within class residual variance. The variance left at class level is also called between class residual variance.

Co-operation

One of the aims of the experiment was to stimulate a student's co-operation with other students. Hence, it was hypothesised that in the experimental classes where students were trained to work together, the level of co-operation would be higher. It can also be presupposed that students' co-operation will increase in time under the experimental condition, that there are differences in the co-operation rates between the students, and that these differences are related to student ability and to gender. Further, it could be hypothesised that there are differences in co-operation processes between classes, and that they are related (at least the level of a class co-operation rate) to class ability. Table 2 shows the outcomes with co-operation as the dependent variable.

The table shows the following:

- (a) There is no effect of time or of gender on co-operation. So, there is a constant level of co-operation in time that is specific for each student as well a constant level of co-operation that is specific for each class over occasions in time.
- (b) There is a positive effect for students' ability (coefficient = .38) on their initial level of co-operation; thus if student ability goes up one unit, we expect a .38 increase in the initial co-operation value.

Table 2. Outcome of multilevel analysis regarding a student’s co-operation as the dependent variable

—	Coefficient	Standard error
<i>Fixed part</i>		
INTERCEPT	34.61	.88
Occasion level		
TIME	—	—
Student level		
GENDER:	—	—
STUDENT ABILITY:	.38	.08
Class level		
MEAN CLASS ABILITY:	—	—
CONDITION:	5.62	.52
<i>Random part</i>		
Occasion level		
Variance	—	—
Student level		
Variance	15.52	.81
Class level		
Variance	1.47	.53
—2*log(1h)	4317.39	

— = n.s. $p = .05$

- (c) The training in basic communication skills as indicated by Condition at class level has a positive effect on the initial level of co-operation in the class, which is consistent with our hypothesis. The outcome means that the initial level of co-operation in trained classes is 5.62 higher than in non-trained classes. However, one has to bear in mind that this score remains constant over time.

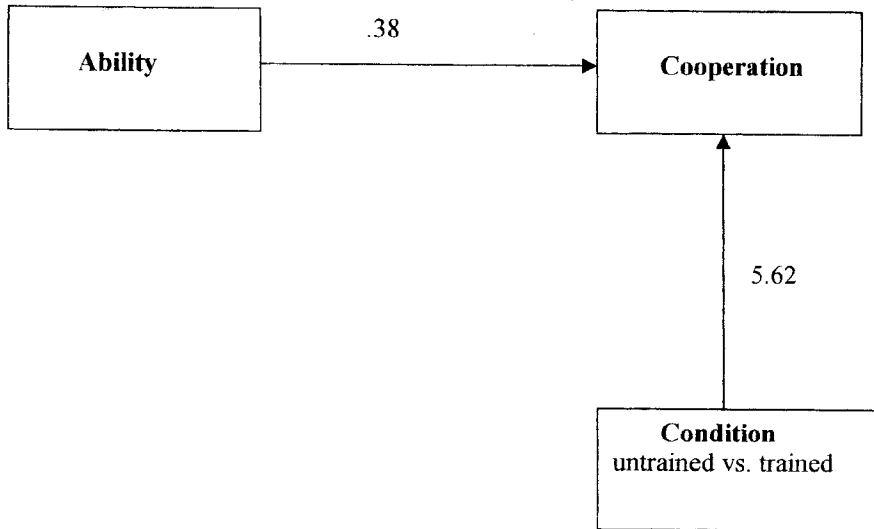
Figure 2 shows how those effects are interconnected.

Unsolicited explanations

The question now asked is: if co-operation is increased by training, how is co-operation related to unsolicited explanations and which factors play a role in the transformation process? We now turn to the results of the analysis in which unsolicited explanation is the dependent variable. We mentioned earlier the research findings in which unsolicited explanations were shown to be less effective than solicited explanations, see also hypothesis II.

From Table 3 the following conclusions can be drawn:

- (a) There is neither any general effect of time on the amount of unsolicited explanations, nor between the students, and hence nor between the classes. So in

Figure 2. Effects of ability and training on cooperation (Table 2)

all respects there is no significant development in time. Thus the time hypothesis can be rejected.

- (b) There is no effect of gender on the amount of unsolicited explanations. Thus also the gender hypothesis can be rejected.
- (c) There is no general effect of co-operation on the giving of unsolicited explanations. Thus the hypothesis about the relation between co-operation and explanations can also be rejected as far as the giving of unsolicited explanations is concerned.
- (d) Student ability contributes to giving unsolicited explanations. If the student's ability goes up with 1 point, the amount of unsolicited explanations given increases with 2.99 points; however these kind of explanations do not originate from co-operation.
- (e) Class ability contributes directly to giving unsolicited explanations. The effect is negative, meaning that if class ability rises with 1 point, the amount of unsolicited explanations decreases with .55 point.
- (f) In the trained condition the initial level of given unsolicited explanations is 1.14 points higher than in the untrained condition; this level remains stable over time. In addition, in the untrained condition the more able students have been stimulated to translate their ability into giving explanations. If the score on a student's ability goes up with one point, .26 more explanations will be given.

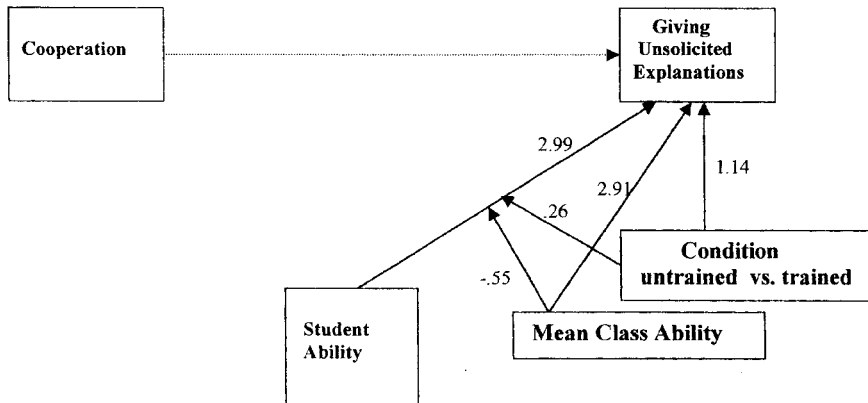
Figure 3 shows the picture. For a clarification of the meaning of the graphical representation see also the description already given at Figure 1, and the elaboration below.

Table 3. Outcome of multilevel analysis regarding unsolicited explanations as the dependent variable

	Coefficient	Standard error
<i>Fixed part</i>		
INTERCEPT	−11.53	4.88
Occasion level		
TIME	–	–
COOPERATION	–	–
Student level		
GENDER	–	–
STUDENT ABILITY	2.99	.78
Effect on between-student differences in slope from COOPERATION by STUDENT ABILITY	–	–
Class level		
Effect on between-class differences in intercept by MEAN CLASS ABILITY	2.91	1.18
CONDITION	1.14	.40
Effect on between-class differences in slope from COOPERATION by CONDITION	–	–
Effect on between-student differences in slope from STUDENT ABILITY by MEAN CLASS ABILITY	−.55	.19
CONDITION	.26	.09
<i>Random part</i>		
Occasion level		
Variance	–	–
Student level		
Variance	18.40	5.14
Covariance (COOP, INTERC)	−.79	.21
Variance COOPERATION	.04	.01
Class level		
Variance intercept	.15	.08

−2*log(1h) is 3345.49
– = n.s. $p = .05$

Figures 3 and 4 need some more clarification. An arrow from box to box refers to the effect of an independent variable on the dependent variable. An arrow from a box to another arrow represents an interaction effect. As a result of the analysis, a coefficient will be given for each significant effect. Let us give an example. In Figure 4, there is an

Figure 3. Outcomes of multilevel analysis: unsolicited explanations (Table 3)

arrow from box (Co-operation) to box (Solicited Explanations) with a coefficient of .36. This means that there is a positive effect from Co-operation to the giving of Solicited Explanations. There is also an arrow from box (Student Ability) to the arrow from Co-operation to Solicited Explanations with a coefficient of .02 (the arrow is depicted vertical). This perpendicular arrow composition represents an effect on the giving of Solicited Explanations, that is, between-student differences in slope from Co-operation by Student Ability. In the analysis 'Co-operation by Student Ability' is an interaction variable. The meaning of this interaction effect can be described as follows: Student Ability has a positive effect on the transformation of Co-operation into the giving of Solicited Explanations. Put differently, the higher a student's ability the more the transformation process of Co-operation into the Giving of Solicited Explanations is enhanced (student ability accelerates). After this clarification, now we turn to the analysis of factors that influence the giving of Solicited Explanations in Table 4 and Figure 4.

Solicited explanations

Finally, the outcomes of the analysis are given for solicited explanations.

From Table 4 the following conclusions can be drawn:

- There is no effect of time nor of gender.
- According to the hypothesis, co-operation positively affects the giving of solicited explanations (coefficient = .36). It appears to be a major factor in co-operative learning. This process is enforced by ability: the higher a student's ability, the stronger the translation of co-operation into giving solicited explanations (coefficient .02). This means that in the context of co-operative learning, high ability students tend to give more solicited explanations to other students; in the end, they will benefit from it. This is a clear differential (interaction) effect.

Table 4. Outcome of multilevel analysis regarding solicited explanations as the dependent variable

	Coefficient	Standard error
<i>Fixed part</i>		
INTERCEPT	−4.65	4.20
Occasion level		
TIME	−	−
COOPERATION	.36	.15
Student level		
GENDER	−	−
STUDENT ABILITY	−.32	.15
Effect on between-student differences in slope from COOPERATION by STUDENT ABILITY	.02	.01
Class level		
Effect on between-class differences in intercept by CONDITION	4.03	.11
MEAN CLASS ABILITY	3.54	1.12
Effect on between-student differences in slope from STUDENT ABILITY by MEAN CLASS ABILITY	−.11	.04
<i>Random part</i>		
Occasion level		
Variance	−	−
Student level		
Variance	1.54	.08
Class level		
Variance	−	−

−2*log(1h) is 2508.73

− = n.s. $p = .05$

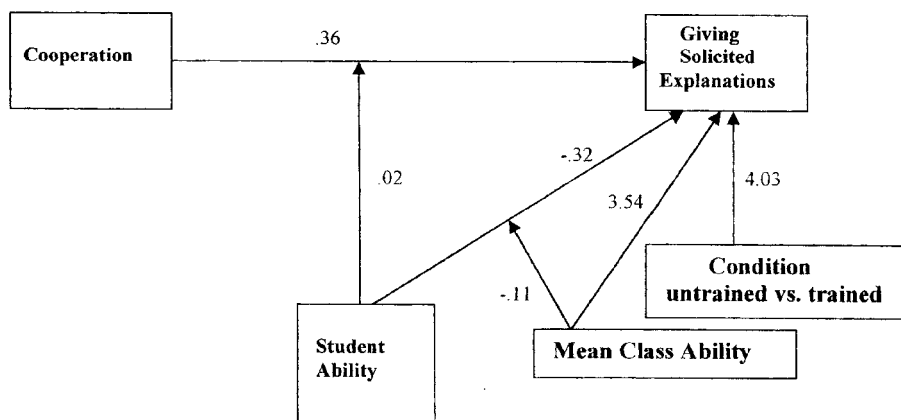
- (c) Student ability contributes negatively to the giving of solicited explanations. If student ability increases with one point, .32 fewer explanations will be given. However, if class ability level increases, this process is depressed: if class ability level rises with one point, and if student’s ability goes up with one point, .11 fewer solicited explanations will be given.
- (d) Mean class ability increases the amount of giving solicited explanations. If class ability increases one point, 3.54 more solicited explanations will be given. Thus, the higher the ability level of a class, the more solicited explanations are given.
- (e) In line with the hypothesis there is a relatively strong positive effect of training in basic communication skills on the giving of solicited explanations. In the trained

condition the initial level of giving solicited explanations increases with 4.03 points.

- (f) There is no traceable effect of condition (training) on the transformation of co-operation into giving of solicited explanations. If co-operation goes up with one point, then the score of giving solicited explanations remains the same. There is no difference between the trained condition and the not-trained condition in this respect. The presupposed mechanism of training in transforming co-operation into the giving of solicited explanations does not work.

Below, again a summarising graph is given (Figure 4).

Figure 4. Outcomes of multilevel analysis: solicited explanations (Table 4)



Discussion and conclusions

The general aim of this study was to determine firstly, the effects of training in basic communication skills on the development of the processes of co-operation and giving explanations in co-operative groups at four points in time and, secondly, to understand the relationship between these two processes. In particular:

1. How do the processes of co-operation and giving explanations develop over time?
2. How are the underlying processes of co-operation and giving explanations related?
3. Which factors, both at student and class level, facilitate or hinder these processes?

In the analysis special attention was directed at understanding the process of how co-operation was transformed into giving solicited explanations. While co-operation

creates a learning environment that is conducive to students helping each other, it does not necessarily follow that this, in turn, will automatically lead to students providing help in the form of explanations. Certainly, giving explanations contributes to achievement (Webb, 1985) and while there is some evidence that solicited explanations are more beneficial for the receiver than unsolicited explanations (Webb, 1991; Webb & Farivar, 1994; Webb *et al.*, 1995), there is no research available on the differential benefits to the helper of giving solicited or unsolicited explanations, and there is even less evidence in the literature of the effects of ability factors, both at the student and class level. Our theoretical model and its corresponding multilevel analysis made it possible to investigate the relations between process variables and how these relations are affected by, e.g., ability factors. For example, we know from literature that there is a relation between the class composition (as indicated by mean class ability) and the outcomes of learning for each student (Brekelmans, Van den Eeden, Terwel, & Wubbels, 1997). However, from 'conventional' observation studies and pre-test post-test studies (Webb, 1992; Dar & Resh, 1994), we do not know how the basic processes in classrooms run in producing these effects. The surplus value of our study, as compared with these studies, is that we (in the context of our observation study and theoretical model) were able to bring at least a part of these underlying processes to the open. Our conclusion, *In the context of co-operative learning, high ability students tend to give more solicited explanations and, in the end, they benefit from it*, is another example of a yield. It is precisely this kind of conclusion which has been made possible by our theoretical model and the corresponding analysis. The surplus value can even be stressed by taking into account that this conclusion has to be regarded in the context of the theoretical model as a whole, which also shows that at the same time counter-balancing forces are at work.

Before presenting the conclusions something needs to be said about the limitations of our study and the levels in the analysis. Firstly, special attention is needed to the power in the analysis. At the class level only eight classes were used in the analysis. For reasons of power it would be desirable to have more units at this level. A similar remark concerns the occasion level. In our analysis only four time points were used which makes the power questionable. Secondly, in the multilevel analysis 'only' three levels were used (occasion, student, class). A fourth level, for example, the small group, was not indicated for several reasons. Although the small group level in the analysis seems to be relevant, our theoretical perspective was primarily directed to the three levels mentioned (occasion, student and class). Beside this, it would have resulted in a very complex model which is very difficult to interpret. Because of the random assignment of students to the small groups, variation between groups is not likely and hence including the small group level seems not useful. Apart from this, slopes and intercepts of small groups (of four students) are 'qualitate qua' less stable and as a consequence their reliability is questionable. After these methodological remarks we now turn to the conclusions.

Against the background of the main hypotheses in our study about the factors influencing the giving of explanations, the following general conclusions can be drawn. The time hypothesis and the gender hypothesis had to be rejected: neither progress in time nor differences between boys and girls could be found. Four out of six hypotheses were confirmed. The hypothesis about the relationship between co-operation and

explanations was confirmed: co-operation was transformed into giving of solicited explanations, and several factors enhancing this process were identified. The student ability hypothesis was also confirmed: high ability students are more successful in transforming co-operation into giving solicited explanations. The mean class ability hypothesis was confirmed: the higher the mean ability level of the class the more explanations were given by the students. Finally, the training in general communication skills had the expected effects on co-operation and the giving of explanations. In addition to the stated hypotheses some interesting unanticipated effects were found.

In the following an elaboration of the foregoing general conclusions is given. The focus is primarily on *solicited* explanations.

Time

The expected development in time concerning co-operation and giving explanation was not realised. Thus the time-hypothesis has to be rejected. In this study, the observations at four different points in time showed high stability, possibly because the first observation did not occur until the third week, by which time the students had already settled into working in their groups. This result is consistent with Webb and Cullinan (1983) who found that students' group interactions were relatively stable over time, but in contrast with the instabilities found in a similar study by Webb (1984). Further research is needed into developmental patterns in time in co-operative groups.

Co-operation and giving explanations

The hypothesis concerning the relationship between co-operation and giving explanations was confirmed. Solicited explanations can be traced back to co-operation and this process is enhanced by ability: the higher students' ability, the more co-operation is transformed into giving solicited explanations. There were some interesting unanticipated differences that were found in the transformation process from co-operation to unsolicited and solicited explanations. Giving unsolicited explanations is not related to co-operation. Co-operation promotes giving solicited explanations and this transformation process is enhanced by student ability, while this mechanism was absent in the case of unsolicited explanations. Thus there is a striking difference regarding the genesis of solicited and unsolicited explanations.

Student ability

Concerning student ability, the research focus was directed to the effect on the transformation process from co-operation to giving explanations. Our analysis clearly shows that high ability students induce more solicited explanations than low ability students. Apart from the fact that in general help on request is more effective, from our analysis we found some indications for the effectiveness of solicited explanations as compared to unsolicited explanations. Although these indications need further investigation the tentative hypothesis is as follows. If one assumes that in general high ability students produce higher quality explanations and are more able to adapt their explanations to the receiver, and if we conclude from our analysis that high ability students give more solicited explanations, then we see why solicited explanations are more effective. In contrast, this finding may help to explain why giving unsolicited explanations is less effective: according to the outcomes of our study, these kinds of

explanations are not embedded in general co-operative activities and not given by more able peers in this co-operative context. We assume that less able peers also are less able to adopt the perspective of the receiver and less able to produce high quality help. Although there are indications for the above tentative hypothesis, i.e., the explanation why solicited explanations are more effective, we have to admit that at the same time forces were at work which respectively mitigated and reinforced the processes which enhance the giving of solicited explanations by more able peers. This balance and counterbalance mechanism are well known in ML analysis of complex interactions as is described by Willms (1985, 1986) in his Balance Thesis.

Gender

The presupposed differences in gender were not found. This is in contrast to findings in, for example, the Netherlands where significant differences in gender have been found. This may have been because the Dutch studies were conducted mainly in the context of a different category of subjects, for example, mathematics, science and physics (subjects in which males often perform better than females) while the subject in the present Australian study is social studies (a subject in which gender differences are often less clear). Another explanation for the results may be that there are differences in the Dutch and the Australian (educational) context. The Netherlands has a larger and more separate special education system in which boys are over-represented. As a consequence the boys in the Dutch regular education system outperform the girls, because the low-achieving boys are already out of the mainstream.

Class-ability level

The class-ability level contributes to the giving of both solicited and unsolicited explanations, over and above the already mentioned effects of student ability. Thus, if the class level rises, students give more explanations. Although both kinds of explanations are promoted by class-ability level, solicited explanations are more prominent. This finding confirms our 'class-ability hypothesis' and is in line with outcomes of research into contextual effects of school-, and class composition (Dar & Resh, 1994; Van den Eeden & Terwel, 1994; Willms, 1985, 1986). By opening the black box of co-operative learning, our analysis enables us to explain why co-operative learning is effective and which factors promote or hinder the process of learning. Effects of co-operative learning can be attributed to peer interactions with more able peers and is promoted by class ability level. These 'rub off' effects are already mentioned by Willms (1985) as a possible explanation of contextual effects. Now we are able to explain this mechanism in terms of specific helping behaviour, for example, the giving of solicited explanations.

Communication skills training hypothesis

Classes trained in basic communication skills had a higher score on co-operation than untrained classes. This finding confirms our 'basic communication skills training hypothesis'. Co-operation can be learned and, in turn, facilitates the giving of solicited explanations (Gillies & Ashman, 1996; Hoek *et al.*, 1997, 1999). There was a direct, relatively strong positive relationship between co-operation and giving solicited explanations, while the direct relationship between co-operation and unsolicited

explanations was much smaller. In the trained groups, giving unsolicited explanations did not occur on the basis of co-operation. However, no differences between the trained and untrained classes were found concerning the transformation of co-operation into solicited explanations. Thus, the presupposed mechanism of acceleration of the transformation of co-operation into solicited explanation in favour of the experimental condition did not work.

In conclusion, we found that, in general, the trained classes (where the training in basic communication skills was implemented) had a higher score on co-operation and giving explanations than untrained classes. The focus of this study was especially directed towards the relationship between these two processes. The results of our study enable us to open a part of the black box by disentangling the processes of co-operation and giving explanations and by showing which factors contribute to the transformation from co-operation to giving explanations. In addition, our analysis shows that, in the context of co-operation, high-ability students tend to give more solicited explanations.

From this finding we infer two possible reasons why the giving of solicited explanations is more beneficial than unsolicited explanations for the help seeker. Firstly, articulating a request for help requires that the help seeker rehearse his/her pre-knowledge and verbalise the need to a helping peer. Secondly, if the help is provided by higher ability students (as our study indicates) who are apparently more able to give higher quality explanations and are more equipped to adapt their responses to the needs of their less able peers, the help will be more effective. These two reasons clarify why solicited explanations are more effective for the help receiver than unsolicited explanations. What about the help-giver? Because high-ability students give more solicited explanations in the context of co-operation, they are involved in the process of taking the perspective of the receiver more often than their low-ability peers. In so doing, they are required to clarify their own understandings and knowledge which, in turn, promotes cognitive reorganisation and learning. This observational study has been useful in explaining how high and low ability students differentially benefit from co-operative learning and how factors such as student ability and mean class ability enhance the processes involved.

The implication for classroom practice is twofold. Firstly, classes and small groups should be trained in order to become socially competent as a basis for the giving and receiving adequate help. Although it may seem possible to train students directly in the giving of adequate explanations, training students in isolated skills, without an adequate context and without connection to content, seems not successful in the long run. From our theoretical point of view a more indirect road appears to be preferable. By training students general communication skills, a co-operative working milieu can be created from which the giving of explanations can develop, as long as the aims are clear and the cognitive demands on students are not too high (see also Hoek *et al.*, 1999). Secondly, there is an implication concerning class and group composition. Each class and small group should include students rich in personal resources to enhance the transformation of co-operation into the giving of high quality solicited explanations.

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Appendix 1

The multilevel model: descriptions and equations

The core of the model consists of two equations. In the first equation, which relates to the occasions of measurement (level-1), a given dependent variable (here giving explanations) is regressed on the time-axis. The simplest corresponding equation is the following one and allows us to describe the process of giving explanations in time and to test the hypothesis on the increase of giving explanations in time.

$$\text{Giving explanations}_{ij} = \beta_{0j} + \beta_{1j} \text{Time}_{ij} + e_{ij} \quad (1)$$

Giving explanations is the dependent variable and Time (here Time = 1, ..., 4) expresses the time variable. This expression corresponds to the equation of the regression of Giving explanations on Time, but it is somewhat more complicated than that. The complication appears in the subscripts, *i* indexes over occasions (*i* = 1, ..., *I_j*) and *j* to students (*j* = 1, ..., *J*). The subscripts *i* and *j* attribute the score to both sources of variance, being the occasion and the student respectively. The intercept, being a constant for all occasions per student, is expressed by β_{0j} , and the regression slope is indicated by β_{1j} . β_{1j} indicates the multiplication factor for predicting a change in the giving of explanations on the base of a change of one point on the scale of *t*. The subscript *j* refers to the differences in the intercepts and the slopes across the individuals. The term e_{ij} expresses the disturbance term belonging to Giving explanations_{*ij*}. The term e_{ij} indicates the deviation of a score of Giving explanations_{*ij*} in a given measurement from the prediction from $\beta_{0j} + \beta_{1j} \text{Time}_{ij}$ for individual *j*.

Next, the inter-individual comparison of β has to be introduced. For each student the intercept β_{0j} can be decomposed into a mean value γ_0 , which is common to all students, and a specific deviation u_{0j} . Moreover, for all students the slope β_{1j} can be decomposed in a common, mean slope γ_1 and a specific deviation u_{0j} .

$$\beta_{0j} = \gamma_0 + u_{0j} \quad (2a)$$

$$\beta_{1j} = \gamma_1 + u_{1j} \quad (2b)$$

This offers:

$$\text{Giving explanations}_{ij} = \gamma_0 + \gamma_1 \text{Time} + u_{0j} + u_{1j} \text{Time} + e_{ij} \quad (3)$$

Equation (3) shows that the scores on Giving explanations of a student *j* in a given measurement *i* are expressed in terms of *t*, the student-related deviations u_{0j} and u_{1j} , and the measurement-bound deviation e_i . It is assumed that there is no correlation between the occasion disturbance term and the two student disturbance terms.

How did we assess the interrelation of co-operation and giving explanations, which are measured at a same measurement moment? The interrelation can be described by extending equation (1) by Cooperation_{ij}, which varies over time. The subscript i indicates the simultaneous measurement of Cooperation_{ij}, Giving explanations_{ij} and Time_{ij}. As a corresponding slope coefficient, β_{2ij} is introduced. This gives:

$$\text{Giving explanations}_{ij} = \beta_{0j} + \beta_{1j} \text{Time}_{ij} + \beta_{2j} \text{Co-operation}_{ij} + e_{ij} \quad (4)$$

Since the time varying variable is analogous to Time of the trajectory of Giving explanations_{ij}, β_{2j} can also vary between the students and covary with β_{1j} .

How do we explain the inter-student relations among differences in developmental courses (trajectories) by student variables? The answer lies in the extenuation of equation (4). Let us restrict ourselves to independent variable Gender_j, which could pretend to explain the between-student variation in the trajectories.

Then, for the intercepts it holds

$$\beta_{0j} = \gamma_{00} + \gamma_{10} \text{Gender}_j + u_{0j} \quad (5a)$$

for the slopes of Time

$$\beta_{1j} = \gamma_{10} + \gamma_{11} \text{Gender}_j + u_{1j} \quad (5b)$$

and for the slopes of Co-operation

$$\beta_{2j} = \gamma_{20} + \gamma_{21} \text{Gender}_j + u_{2j} \quad (5c)$$

Here, the variances of the intercept parameter β_{0j} and slope parameters β_{1j} are reduced by the individual constant variable, Gender_j. This analysis enables us to answer questions like 'Does the mean level of giving explanations of students depend on their gender?' (regarding the intercept), and 'Does the change in students' giving explanations level over time depend on their gender?' (regarding the slope).

In an analogous way, a question like the following can be answered. Does the relationship between Giving explanations_{ij} and the varying independent variable, Cooperation_{ij}, depend on Gender_j (a differential effect regarding the relationship of giving explanations and co-operation)?

In the present study the third level is the class, which is indicated by the subscript k (we did not mention this earlier for sake of simplicity). Let us take the class variable Condition (Training), the corresponding coefficient by α , and the disturbance term by v_k .

$$\gamma_k = \alpha_{0k} + \alpha_{1k} \text{Condition}_k + v_k \quad (6)$$

The formulae and interpretations run analogously. This model allows us to test the set of hypotheses mentioned. In the analysis the program MLn has been used (Rasbash *et al.*, 1995). In the analysis we investigated the validity of the entire model using a forward procedure, except for the variable Time which was kept in the analyses throughout.

